[REPRINTED FROM THE SIXTH REPORT OF THE BUREAU OF MINES, ONTARIO.]

Rocks and Rock Structures

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According to the commonly accepted theory the earth and the other members of the solar system were at one time in a fused or molten condition; hence the first rocks formed on our globe (through the cooling of the molten mass) belonged to the class which is known as the Igneous or heat-formed rocks. These rocks are still being formed through the cooling of fluid matter which rises from depths in the interior of the earth through fissures in the crust, to or towards the surface. Rocks of the earth's crust. Igneous rocks.

After the molten material had solidified at the earth's surface, it would be acted upon by the atmosphere, water and other agencies, and be broken down to a greater or less extent to form gravel, sand or clay, just as we see masses of rock, such as cliffs, being worn down by these agencies at the present day. The materials thus formed, which are fragmental in nature, together with rocks formed by the deposition of the remains of plants and animals, make up the greater part of the class known as Aqueous or water-formed rocks. They are given this name on account of water being the chief agent in their formation. They are known also under the names sedimentary, fragmental and clastic. Aqueous rocks.

The sorting action of water on the loose material into which rock masses are broken may be seen along the shore of any lake. The coarsest material, gravel, is deposited near the shore, while the sand is deposited in layers in deeper water, and the finest material or clay is deposited still farther from the shore line. Through the effects of pressure and cement substances these loose products are solidified in time into beds or strata of conglomerate sandstone and shale.

Metamorphic rocks.

If these aqueous rocks are subjected to greater pressure and heat, they become very compact and their characters are much altered. They become more or less crystalline in appearance and are then known as Metamorphic or altered rocks, or as the Crystalline schists.

We thus have three kinds, or three great classes of rocks, making up the crust or outer part of the earth, viz., the Igneous, Aqueous and Metamorphic rocks.

Metamorphic rocks are also formed from those of the igneous class through the agency of pressure and chemical action. Thus, while some gneisses are known to be altered aqueous rocks, it has been proved that others have been formed through the alteration or metamorphism of igneous rocks.

Forms of igneous rocks.

The earth is constantly losing heat and diminishing in size. The interior as it loses heat tends to shrink away from the external cool and solid crust. This causes the crust to become folded and wrinkled, as the cooling goes on. In places the side or lateral pressure on the folds becomes so great that they are cracked and broken across. The fissures or cracks thus formed in the crust sometimes reach to great depths, so that the highly heated matter of the interior finds a passage to the surface. On cooling it gives rise to surface-formed igneous rocks, or, as they are generally called, volcanic rocks. The material of which these are composed having been exposed at the surface of the earth cools quickly, after the manner of the molten material which is drawn from a furnace. Hence we find that volcanic rocks are often slag-like or glassy in appearance. Through the folding and rupturing of the rocks, the crust has fissures and cavities formed on its under surface. Into these spaces molten matter also makes its way, but here it loses its heat or cools slowly, and gives rise to rocks which are coarse grained and crystalline, and not glassy or slag-like in appearance. Igneous rocks of this class are called plutonic rocks, since they are formed deep down beneath the surface of the earth. There is also another class of igneous rocks, which is intermediate in character, or forms a connecting link between the volcanic and the plutonic classes. This class of igneous rocks is known as the dike rocks. They represent molten matter which has cooled in narrow fissures in the crust, and hence has lost heat through contact with the walls of the fissures more rapidly than did the matter which gave rise to the plutonic rocks, but not so rapidly as did the volcanic rocks. Dike rocks are usually much finer grained than those of the plutonic class, and some of the minerals of which they are composed often have a definite crystal outline, giving the rocks a porphyritic structure. They also differ from the volcanic rocks in not being glassy, and in other characteristics.

Volcanic rocks.

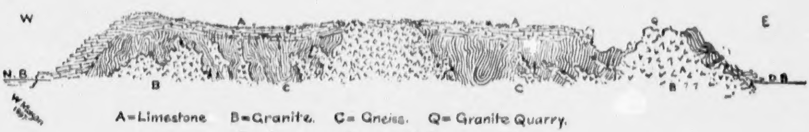
Plutonic rocks.

Some of the fissures formed by the fracturing of the earth's crust do not extend down to the highly heated interior, and hence are not filled with molten material. In course of time however most of these fissures are filled with mineral matter, which is deposited from solution in the waters which circulate through the crevices and openings in the rocks. The material thus

deposited forms what has been called vein rocks. These materials filling fissures are what is known as mineral veins. While dikes and fissure veins are similar in form, the latter are of aqueous origin, while the former are of igneous formation. Vein rocks.

It is natural that the older rocks should in most cases be more broken and fractured than the newer; hence veins are more frequently found in them. In the process of folding, openings are made between the beds of rocks, and moreover cavities are made in rocks through the solvent action of water. These openings and cavities are filled in the course of time in the same way as are some fissures, by the deposition of material from solution. We thus get mineral deposits or ore bodies of various forms. Origin of mineral veins.

If a series of beds of rocks has been folded and then exposed to erosive or breaking down action, through the agency of water and the atmosphere, the tops of the folds may be worn off. We then get a structure such as is shown by the gneiss C in the following figure. Barriefield Common, Kingston.



Section across Barriefield Common, Kingston.

A—Limestone (an aqueous rock.) B—Granite (an igneous rock). C—Gneiss (a metamorphic rock.)

Rocks of four ages are shown in the section, viz: gneiss; granite, which cuts through the gneiss and is therefore the younger of the two; limestone, which overlies both the granite and the gneiss and contains fragments of the former, and is therefore the youngest of the three; boulders and other loose material, which overlie the limestone and are hence the youngest rocks present.

Several common geological terms may be explained by means of the section, e.g. "contact," the point of junction of the limestone with the gneiss or granite; "unconformity," the beds of limestone lying on the upturned edges of the gneiss. The layers of the gneiss make an angle with the horizontal. The gneiss is therefore said to "dip" at a certain angle. The horizontal direction or the course of the upturned edges, which is perpendicular to the line of dip, is spoken of as the "strike." The granite appears at the surface of the ground, or forms an "out-crop." A mass of igneous rock exposed at the surface in a more or less rounded or irregular form is spoken of as a "boss." Narrow fissures in the gneiss are filled by granite. Such structures are known as "dikes." The foldings in the gneiss show "anticlines" or ridge-like forms, and "synclines" or trough-like forms. The bedded structure in the limestone is spoken of as "stratification," each bed being called a stratum. The gneiss shows a layer-like structure also, but the layers are not so regular as those in the limestone, and are more or less finely bent and crumpled. This structure in gneiss and other crystalline rocks is spoken of as "schistosity"—the rocks are said to Illustrations of geological terms.

have a schistose structure. The granite is not arranged in layers, and is called a "massive" rock.

IGNEOUS ROCKS.

Classification of igneous rocks.

The Igneous rocks may be divided as we have seen into three groups—plutonic, dike and volcanic. The members of each group are again subdivided, according to the percentage of silica they contain, into acid, intermediate and basic rocks. If a rock contains over 65 per cent. of silica, it is spoken of as an acid rock; if its percentage of silica is between 50 and 65, it is said to be intermediate in composition. Rocks containing less than 50 per cent. of silica are said to be basic.

The names given to Igneous rocks, unless they are perfect glasses, depend on the minerals they contain—hence also on their percentage of silica—and on their structure, that is on the form and arrangement of their constituent minerals.

The following tabular arrangement of the Igneous rocks shows the way in which they are classified according to the description given above. Only the more commonly occurring rocks are shown in the table, and since many of the dike rocks have been but little studied, and are moreover difficult to determine without recourse to refined methods of investigation, their position is not shown in the table. The pink and light colored varieties of these may be simply called granite or syenite dike rocks, while the name "trap" may be applied in the field to the fine grained basic rocks, whose true character cannot be made ou in hand specimens.

	Chief felspar=ORTHOCLASE		Felspar=PLAGIOCLASE	
	with usually MICA (or, and) HORNBLENDE (or, and) AUGITE		with HORNBLENDE (or, and) MICA	with DIALLAGE.
	+ QUARTZ.	−QUARTZ.		
Plutonic.—(Structure=coarse grained.)	Granite.	Syenite.	Diorite.	Gabbro.
Volcanic.—(Structure=more or less glassy.)	Rhyolite. Obsidian. Pitchstone. Pumice.	Trachyte.	Andesite.	Basalt. Diabase.

The mineralogical composition of the plutonic rocks can be made out by a glance at the table; e.g., it is seen that we may have a syenite which is composed of mica and orthoclase.

Each volcanic rock corresponds in chemical composition to the plutonic rock in the same column. Usually however the volcanic rocks are incompletely crystallized. They contain more or less glass, which is represented in the corresponding plutonic rocks by mineral grains.

About the names of rocks.

There are no hard and fast lines between rocks. We find one group or class passing gradually into another. Thus, one might get a rock which could be called either a basic granite or an acid diorite. Hence too much stress should not be placed on a name. If we know the characteristics of a rock, that is, can give a description of it, it matters very little for our own convenience whether we give a name to it or not. A name serves merely as a short general description, but as many closely related rocks, varieties of granite for example, differ from one another in so many particulars, it is necessary for us if we wish to give the characteristics of a certain granite to state something more than its mere name. The characters of the Aqueous rocks are less difficult in most cases to determine than those of the Igneous class, and no tabular arrangement is required in their description. Some of the more common Aqueous rocks are conglomerate, sandstone, shale and limestone. The Metamorphic rocks also do not require a complex classification. Some of the more common members of this class are gneiss, mica schist, quartzite, slate and crystalline limestone

Only very brief descriptions are here given of the rocks in the catalogue. Kemp's Handbook of Rocks, (the author, Columbia College, New York, price $1.50), will be found a good book in which to read up details. This book also contains an excellent glossary of the names of rocks and of other lithological terms.

Specimens of igneous rocks.

185 and 186. Granite. Granites are coarse grained rocks, color gray or light red, and are composed typically of quartz, orthoclase, or other acid felspar, and mica, biotite and muscovite. Mica may be replaced in whole or in part by hornblende. The ferromagnesian constituents, biotite and hornblende, in granite are often decayed, and the felspar is often altered to kaolin, or clay, when the rock has been subjected to atmospheric influences. The value of a granite mass for industrial purposes depends on a number of factors, among which might be mentioned color, homogeneity in texture, power of resisting decay, ease in quarrying and facilities for transportation. Practically all the granite used in Ontario for monumental purposes is imported. There are undoubtedly valuable varieties of it in the Province, but it is difficult to overcome trade prejudices. An altered granite found in the gold regions of northwestern Ontario and in other parts of the world is sometimes known as protogine, but the name is not used so much as formerly. Granites have in some cases been changed into gneiss through the action of pressure and other agencies.

Some of the most common accessory minerals of granite are magnetite, apatite, tourmaline and zircon. Cassiterite, or tin-stone, is also found in certain varieties of granite.

Granites are found in bosses and dikes cutting through other rocks, and they are often overlain by sedimentary rocks.

187 Pegmatite. This is a coarse grained rock made up of the same minerals as are found in granite. Quartz and light colored felspar however predominate in this rock, and mica when present is usually light colored. The rock is often a storehouse for rare and valuable minerals, among which may be mentioned tin-stone, tourmaline, corundum and beryl. Graphic granite is a variety in which the gray quartz is so arranged through the white felspar as to present the appearance of characters in the ancient Grecian or Phoenician alphabet.

188. Syenite. Coarse grained; color usually reddish or gray. This rock has much the appearance of granite, and differs from it only in the absence of quartz Hence a syenite may be called a quartzless granite. While the percentage of silica in granite, on account of the presence of quartz, is high, 65 to 80, making an acid rock, the silica in syenite is in a considerably lower percentage. Hence syenite is said to be a rock of intermediate composition—its percentage of silica lying between that of granite and the basic rocks, or those low in silica. A highly interesting rock known as nepheline syenite is found in the northern part of the county of Hastings, Ontario. In it the rare mineral nepheline plays the part of a felspar.

189. Diorite. Usually a rather coarse grained rock and darker in color than syenite, from which it differs by having plagioclase instead of orthoclase as its felspathic constituent. Typical diorite consists essentially of plagioclase and hornblende.

190. Gabbro. Often very coarse grained; usually dark in color. It contains a lower percentage of silica than diorite, and typical specimens are composed essentially of basic plagioclase and the variety of pyroxene known as diallage. Where hypersthene is present as an essential constituent the rock is known as norite. Anorthosite, a rock related to gabbro, consists essentially of lime-soda felspar. It may be mistaken for crystalline limestone, but is harder. Gabbro often contains much magnetite, and it is believed by some authorities that certain magnetite deposits found associated with this rock are of igneous origin, and have been formed at the same time and out of the same molten mass as the gabbro with which they are associated. A similar theory has been proposed to account for the origin of the nickeliferous pyrrhotite deposits of Sudbury, which are associated with gabbro like rocks.

191. Obsidian. This is a natural glass. It is, in some cases, a volcanic representative of the plutonic granite, as the two rocks agree in chemical composition. Their structural difference, one being a glass and the other a coarsely crystalline granular rock, is to be accounted for by their difference in origin. Granite originated deep down beneath the surface of the earth by the gradual or slow cooling of molten matter. On the other hand, the molten material from which obsidian was formed poured out at the surface of the earth and lost heat so quickly that there was not time for the molecules of the minerals to arrange themselves so as to form grains. The whole mass became solid in a comparatively short time. Rhyolite is like granite in chemical composition, but is more or less glassy. Sometimes it is composed of crystals of orthoclase and granules of quartz set in a glassy groundmass.

Rhyolite.

192. Pumice. This rock is a porous or vesicular obsidian. Pitchstone, which is resinous in appearance, may be looked on as a devitrified obsidian. The name felsite is sometimes given to a devitrified glassy rock, fine grained and compact in structure, and consisting of orthoclase intimately mixed with some quartz. It has a flint-like fracture, and sometimes is very dull or stony in appearance. The term felsite is however, like the names of some other rocks, so differently used by different writers that its reputation as a rock name is lost.

193. Trachyte. A volcanic rock which corresponds to syenite in chemical composition, light gray in color and presenting a dull appearance. Sometimes looks somewhat like a fine-grained limestone.

194. Andesite. This is the volcanic representative of diorite.

195. Basalt. Corresponds in chemical and mineralogical composition to gabbro, and is one of its volcanic representatives. It is a dark, heavy, close-grained rock, and is often known under the name of trap. It often possesses a columnar structure, and frequently contains cavities through it which are filled with agates, zeolites or other minerals. Basalt is a characteristic rock on the north shore of lake Superior.

196. Columnar Trap.

197. Diabase. This is another volcanic representative of gabbro. It differs from basalt in structure. Typically it consists of the two essential minerals, plagioclase and augite, but olivine may also be present, when the rock is known as olivine diabase. Diabase tends to weather at the surface of the ground into spheroidal or ball-like masses. When examined in thin sections or slices under the microscope the plagioclase is seen to be in lath-like strips which are set into the augite. On a weathered surface of the rock, in hand specimens, the plagioclase laths may be seen as very fine short white lines, a characteristic by which the rock may be distinguished. Of course if the surface examined is much rusted or decomposed the lines do not come out. Various accessory minerals are found in the rock. It forms dikes and masses in different parts of Ontario, notably in the vicinity of Sudbury.

AQUEOUS ROCKS.

198. Conglomerate. This is composed of rounded fragments of various rocks or minerals cemented together by calcium carbonate, iron oxide or other material. A mass of it may be called a solidified gravel bed. Samples of Aqueous rocks.

199-200. Sandstone. Composed typically of quartz grains of various colors cemented together, but the rock may be more or less impure from the presence of other minerals. It possesses a bedded or stratified structure.

201. Shale. This rock is composed typically of clay. It is very fine-grained and occurs in very thin layers.

202. Clay. The character and uses of this material are well known.

203. Kaolin. Ordinary clay is an impure form of this substance.

204. Limestone. Rocks of this class differ much in color, grain and composition. Typically they are composed of the mineral calcite, together with more or less dolomite. They are formed through the accumulation of

shells and other calcareous structures of various fresh water and marine organisms, such as mollusca and corals. Many limestones contain fossils, thus showing their organic origin, but usually the calcareous material is more or less crushed or broken up. Some limestones have originated entirely through the deposition of calcium carbonate from aqueous solutions.

205. Lithographic Stone (Limestone).

206. Hydraulic Limestone.

207. Dolomitic Limestone.

208. Calcareous Tufa. In this rock the calcium carbonate of which it is composed has been deposited from solution. The rock is more or less porous in appeorance.

209. Shell Marl. This rock is made up almost entirely of the calcareous shells of small organisms.

210. Chalk. This has a similar origin to shell marl but is usually purer and more compact.

211. Tripolite. Is formed by the accumulation of the shells of minute organisms known as diatoms. It is composed of silica and is used as a material for polishing.

METAMORPHIC ROCKS, ETC.

Samples of Metamorphic rocks.

212-213. Gneiss. Is similar in mineralogical composition to granite, but is distinguished from this massive rock by having its minerals arranged in a more or less layer-like form.

214. Mica Schist. Composed essentially of the minerals quartz and mica. It splits readily into thin layers or foliæ.

215. Hornblende Schist. Has a more massive appearance than mica schist, and its chief mineral is hornblende.

216. Quartzite. Is a hardened or metamorphosed sandstone.

217. Quartzite (flexible) or Itacolumite.

218. Slate or Argillite. The term slate is used somewhat loosely, but should be restricted to a rock which is a metamorphosed shale (clay). It splits or cleaves in directions independent of the original bedding.

219. Crystalline Limestone. This is similar in composition to ordinary limestone, but is crystalline in appearance. Some varieties used in the arts are known as marble.

220. Calc-schist. Is a variety of crystalline limestone.

221. Vein and Country Rock. This specimen is taken from the contact of the vein and country rock at the Deloro gold mine, Marmora, Ont.

222. Thin Section of Rock. This specimen shows a thin section or slice of diabase prepared for examination under the microscope.

223. Photograph. Shows the appearance which a thin section of diabase presents under the microscope. Photographs taken of objects through the microscope are known as photomicrographs.

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